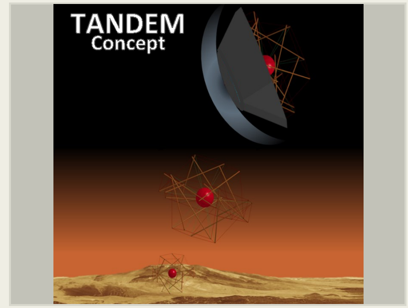
NASA Innovative Advanced Concepts

Light Weight Multifunctional Planetary Probe for Extreme Environment Exploration and Locomotion

Completed Technology Project (2016 - 2017)

Project Introduction

The Tension Adjustable Novel Deployable Entry Mechanism (TANDEM) is a specially configured tensegrity structure that is designed to act as the frame of a deployable heat shield. TANDEM combines the infrastructure used for the Entry, Decent, and Landing sequence as well as on-the-ground locomotion into a single multifunctional system. Reusing the same infrastructure for every section of the mission makes TANDEM one of the most efficient systems ever proposed. Although its touchdown mass may be higher than other landers, the versatility of its components translates to a tremendous mass reduction for the whole mission. TANDEM is an entry vehicle and lander for planetary exploration class probes. It utilizes a semi-rigid, 3-D woven carbon-cloth deployable heat shield. What separates TANDEM from other deployable entry vehicles is its use of tensegrity structure as the frame of the deploying mechanism. The use of tensegrity robotics for entry vehicles is a currently unexplored concept, providing numerous potential benefits during entry and descent. These benefits include a mass efficient mechanism for actively guided entry, active control of L/D ratio, as well as active control of aerodynamic center. Like most tensegrity concepts, it inherently provides omni-directional protection on impact. However, due to the unique shape of the vehicle, it can actively adjust its configuration for optimal landing. If unforeseen circumstances cause the lander to turn upside-down, TANDEM can be programed to change its aerodynamic center and reorient itself. Alternatively, it can adjust its outer circumference to provide a safer landing based on its free fall orientation. This adds a remarkable level of reliability and safety to any mission using the TANDEM concept. Conventional tensegrity locomotion depends largely on actuation of the outer cables. This requires mechanical devices in each strut to reel in the cables. However, for extreme environment applications such a system can prove infeasible as it requires each strut to be protected from the environment. This in turn can cause the lander to be prohibitively heavy. On the other hand, the TANDEM technology can be effectively applied for locomotion through using only inner cable actuation. The locomotion mechanisms can hence be housed in a central payload module, using a common insulation and pressure vessel. TANDEM is designed to enable landing at any orientation and can traverse significantly rougher terrain than existing rovers. This means new landing sites can be reached. Instead of landing in low risk areas then traveling to the closest area of scientific interest, missions using TANDEM can land directly in the region of interest. The TANDEM concept provides a high level of adaptability and controllability which can be utilized in entry, descent, landing, and for locomotion by actuating specific inner cables. This opens all new avenues in utilizing multifunctional exploration systems with enhanced maneuvering options. Additionally, TANDEM presents a robust, low weight method of locomotion that does not require ultra-high temperature mechanisms for mobility in extreme environments. These attributes make it a superior concept for near- to mid-term missions.



Artist’s rendering of the TANDEM concept showing a deployable heat shield and tensegrity structure for high risk landing zones for extreme environmental missions.

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Anticipated Benefits

The use of tensegrity robotics for entry vehicles is a currently unexplored concept, providing numerous potential benefits during entry and descent. These benefits include a mass efficient mechanism for actively guided entry, active control of L/D ratio, as well as active control of aerodynamic center. Like most tensegrity concepts, it inherently provides omni-directional protection on impact. However, due to the unique shape of the vehicle, it can actively adjust its configuration for optimal landing. If unforeseen circumstances cause the lander to turn upside-down, TANDEM can be programed to change its aerodynamic center and reorient itself. Alternatively, it can adjust its outer circumference to provide a safer landing based on its free fall orientation. This adds a remarkable level of reliability and safety to any mission using the TANDEM concept. Conventional tensegrity locomotion depends largely on actuation of the outer cables. This requires mechanical devices in each strut to reel in the cables. However, for extreme environment applications such a system can prove infeasible as it requires each strut to be protected from the environment. This in turn can cause the lander to be prohibitively heavy. On the other hand, the TANDEM technology can be effectively applied for locomotion through using only inner cable actuation. The locomotion mechanisms can hence be housed in a central payload module, using a common insulation and pressure vessel. TANDEM is designed to enable landing at any orientation and can traverse significantly rougher terrain than existing rovers. This means new landing sites can be reached. Instead of landing in low risk areas then traveling to the closest area of scientific interest, missions using TANDEM can land directly in the region of interest. The TANDEM concept provides a high level of adaptability and controllability which can be utilized in entry, descent, landing, and for locomotion by actuating specific inner cables. This opens all new avenues in utilizing multifunctional exploration systems with enhanced maneuvering options. Additionally, TANDEM presents a robust, low weight method of locomotion that does not require ultra-high temperature mechanisms for mobility in extreme environments. These attributes make it a superior concept for near- to mid-term missions.

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Virginia Polytechnic Institute and State University (VA Tech)

Responsible Program:

NASA Innovative Advanced Concepts

Project Management

Program Director:

Jason E Derleth

Program Manager:

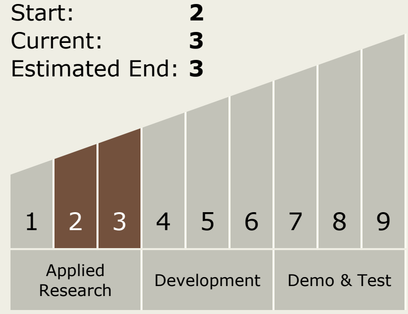
Eric A Eberly

Principal Investigator:

Javid Bayandor

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



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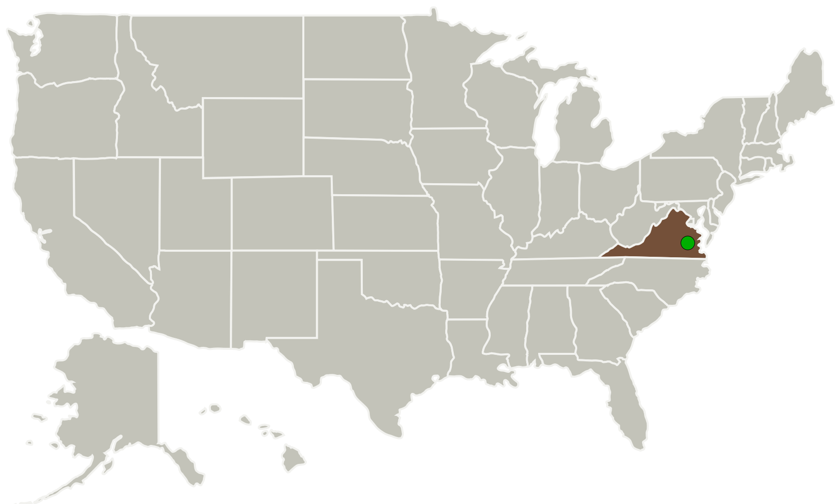
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Virginia Polytechnic Institute and State University(VA Tech)	Lead Organization	Academia	Blacksburg, Virginia
Langley Research Center(LaRC)	Supporting Organization	NASA Center	Hampton, Virginia

Primary U.S. Work Locations
Virginia

Project Transitions

July 2016: Project Start

Technology Areas

Primary:

- TX09 Entry, Descent, and Landing
  └ TX09.2 Descent
    └ TX09.2.1 Aerodynamic Decelerators

Target Destinations

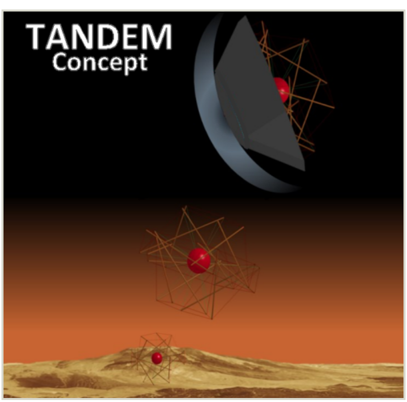
The Moon, Mars, Others Inside the Solar System

June 2017: Closed out

Closeout Summary: The demand to explore new worlds requires the development of advanced technologies that enable la nded science on uncertain terrains or in hard to reach locations. As a result, contemporary Entry, Descent, Landing, (EDL) a nd additional locomotion (EDLL) profiles are becoming increasingly more complex, with the introduction of lifting/guided ent ries, hazard avoidance on descent, and a plethora of landing techniques including airbags and the skycrane maneuver. The inclusion of each of these subsystems into a mission profile is associated with a substantial mass penalty. This report explor es the new all-in-one entry vehicle concept, TANDEM, a new combined EDLL concept, and compares it to the current state o f the art EDL systems. The explored system is lightweight and collapsible and provides the capacity for lifting/guided entry, guided descent, hazard avoidance, omnidirectional impact protection and surface locomotion without the aid of any addition al subsystems. This Phase I study explored: 1. The capabilities and feasibility of the TANDEM concept as an EDLL vehicle 2. Extensive impact analysis to ensure mission success in unfavorable landing conditions, and safe landing in Tessera regions 3. Development of a detailed design for a conceptual mission to Venus. As a result of our work it was shown that: 1. TANDE M provides additional benefits over the Adaptive, Deployable Entry Placement Technology (ADEPT) including guided descent and surface locomotion, while reducing the mass by 38% compared to the ADEPT-VITaL mission1 2. Demonstrated that the design of tensegrity structures, and TANDEM specifically, grows linearly with an increase in velocity, which was previously u nknown 3. Investigation of surface impact revealed a promising results that suggest a properly configured TANDEM vehicle can safely land and preform science in the Tessera regions, which was previously labeled by the Decadal Survey as, largely inaccessible despite its high scientific interest2 . This work has already resulted in a NASA TM and will be submitted to the J ournal of Spacecraft and Rockets1 .

Closeout Link: https://www.nasa.gov/feature/light-weight-multifunctional-planetary-probe-for-extreme-environment-expl oration-and

Images



Project Image
Artist’s rendering of the TANDEM concept showing a deployable heat shield and tensegrity structure for high risk landing zones for extreme environmental missions.
(https://techport.nasa.gov/image/102081)

Links

NASA.gov Feature Article
(https://www.nasa.gov/feature/light-weight-multifunctional-planetary-probe-for-extreme-environment-exploration-and)